UNITED STATES PATENT APPLICATION

FOR

METHOD FOR PICKING SEMICONDUCTOR CHIPS FROM A FOIL

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SPECIFICATION

TITLE OF INVENTION

Method for picking semiconductor chips from a foil

PRIORITY CLAIM

[0001] The present application claims priority under 35 U.S.C § 119 based upon Swiss Patent Application No. 2002 2022/02 filed on November 29, 2002.

FIELD OF THE INVENTION

[0002] The invention concerns a method for picking semiconductor chips from a foil.

BACKGROUND OF THE INVENTION

[0003] With the mounting of semiconductor chips onto a substrate, the substrate is fed by a transport device in steps to a dispensing station where adhesive is applied and then to a bonding station where the next semiconductor chip is placed. The semiconductor chips adhere to a foil clamped in a frame and are presented on a so-called wafer table, there they are picked one after the other by a device known as a Pick and Place, transported and placed onto the substrate. The Pick and Place device comprises a bondhead with a chip gripper for picking the semiconductor chips whereby the chip gripper can be deflected in vertical direction in relation to the bondhead against a force, the so-called pick force when picking from the foil or bond force when placing onto the substrate. The picking and detaching of the semiconductor chip from the foil as well as the placing of the semiconductor chip onto the substrate are meticulous processes. When picking the semiconductor chip the problem arises that its surface is not always at the same height and therefore it is not always known at which height the chip gripper should come to a standstill. On the one hand, the chip gripper should be lowered at the highest speed possible so that the cycle time stays as short as possible. On the other hand, the chip gripper should strike the semiconductor chip with as little impulse as possible and therefore at lower speed so that the semiconductor chip is not damaged.

[0004] Today, two methods are known in order to determine the height, designated as the z height, of the surface of the semiconductor chips when located on the foil or the height of the surface of the substrate. With the first method, instead of the chip gripper a measuring head is installed on the bondhead with which the z height at which the measuring head strikes the semiconductor chip or the substrate can be measured. With the second method, the current, which flows through the lowering drive of the bondhead, is monitored and a sudden increase in this current is interpreted as the striking of the

chip gripper on the semiconductor chip or the substrate.

[0005] The object of the invention is to further improve the process for picking the semiconductor chip from the foil.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The picking of a semiconductor chip from a foil takes place by means of a chip gripper, which can be deflected on a bondhead in a predetermined direction designated as the z direction, and with the aid of a needle. The chip gripper bears pneumatically on the bondhead so that the pick force exerted by the chip gripper on the semiconductor chip is independent of the degree of deflection of the chip gripper. Furthermore, an inductive sensor is integrated into the bondhead for the precise measurement of the deflection of the chip gripper in z direction, ie, the z height of the chip gripper. The inductive sensor also serves as a touchdown sensor.

[0007] The pick process in accordance with the invention distinguishes itself by the following steps:

a) Lowering the chip gripper to a height z_0 that is greater than the average height of the surface of the semiconductor chips so that the chip gripper does not yet touch the semiconductor chip;
b) Raising the needle to a predetermined height z_1, whereby the needle raises the semiconductor chip in order to bring the semiconductor chip into contact with the chip gripper and then to increase the z position of the chip gripper, and
c) Raise the chip gripper whereby the semiconductor chip detaches itself from the needle.

[0008] Each time a new foil with semiconductor chips is presented for processing, the height z_0 is re-determined in an adjustment phase with the aid of the inductive sensor. The height is also designated as z position.

[0009] In addition, with certain applications, at step c the chip gripper is moved away from the needle at the highest possible speed in order to avoid turning and/or shifting of the semiconductor chip.

[0010] Furthermore, after step b, it is possible to measure the deflection of the chip gripper in relation to the bondhead and from this to determine the actual height of the surface of the picked semiconductor chip in order to continuously or periodically update the height z_0.

[0011] As the inductive sensor is integrated into the bondhead, the height z_0 can be determined with very high accuracy. For this reason, in step a, it is also possible to lower the bondhead to a height z_0 which is less than the average height z_M of the surface of the semiconductor chips so that the chip gripper is deflected in relation to the bondhead on striking the semiconductor chip. However an adequate condition is that the chip gripper bears pneumatically on the bondhead. The distance by which the height z_0 in this case is less than the height z_M, which is designated as the overtravel distance, can be kept much lower than normal in prior art on the one hand because of the precise knowledge of the height z_M and on the other hand because of the pneumatic bearing of the chip gripper which delivers a force independent of the degree of deflection. In this way, when the chip gripper strikes the semiconductor chip, the

bondhead is already immediately before the end of the braking phase. As a result, the striking speed of the chip gripper and therefore the impact on the semiconductor chip is less than in prior art.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0012] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more embodiments of the present invention and, together with the detailed description, serve to explain the principles and implementations of the invention. The figures are not to scale.

Fig. 1	is a front elevational diagram illustrating a first embodiment of a bondhead of a Die Bonder that has an integrated touchdown sensor.
Fig. 2	is a characteristic curve of the touchdown sensor.
Fig. 3	is a diagram illustrating the operation of an embodiment of the invention.
Fig. 4A, 4B and 4C	are snapshots illustrating motion of the bondhead.
Fig. 5	is a diagram illustrating the operation of an embodiment of the invention.
Fig. 6	is a front elevational diagram illustrating a second embodiment of a bondhead of a Die Bonder.
Fig. 7	is a diagram illustrating the operating of an embodiement of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Fig. 1 shows a first embodiment of a bondhead 1 of a Die Bonder whereby only those components of the bondhead 1 are presented and described that are necessary for the understanding of the invention. The bondhead 1 belongs to a Pick and Place system, that serves to pick semiconductor chips presented on a wafer table and to place them onto a substrate. With this embodiment, the bondhead 1 is lowered in a direction designated as z direction for picking the semiconductor chip, raised again, transported to the substrate and lowered again for placing the semiconductor chip onto the substrate. For the precise movement of the bondhead 1 in z direction, a not presented drive and a not presented measuring system for measuring the z position of the bondhead 1 are present. The drive can either lower and raise the bondhead 1 in z direction in relation to the Pick and Place system or it can lower and raise the entire Pick and Place system together with the bondhead 1 in z direction. Such a Pick and Place system is known, for example, from US 6185815. The bondhead 1 comprises a chip gripper 2 that can be deflected in z direction in relation to the bondhead. The chip gripper 2 consists of a metal shaft 3 at the lower end of which a suction organ 4 is attached to which vacuum can be applied. The chip gripper 2 bears pneumatically, as frictionless as possible in the bondhead 1. The bondhead 1 has a shaft 5 movable in z direction at the lower end of which a magnet 6 is attached so that the chip gripper 2 is secured to the bondhead 1 by means of magnetic force and can be exchanged in a simple manner. The upper end of the shaft 5 is secured to a piston 7, which is guided in a cylindrical pressure chamber 8. A predetermined pressure p as well as overpressure/vacuum can be applied to the pressure chamber 8 via a connector 9. The pneumatic bearing of the chip gripper 2 on the bondhead 1 produces a pick force independent of the degree of deflection of the chip gripper 2. When overpressure is applied to the pressure chamber 8, then the piston 7 is pressed against the wall 10 serving as a stop. This limit stop of the piston 7 and therefore also the chip gripper 2 is designated as the resting position of the chip gripper 2 in which the chip gripper 2 is not deflected in relation to the bondhead 1.

[0014] The bondhead 1 has an integrated sensor, designated as touchdown sensor that consists of a plate 11 made of metal, for example aluminium, and an electric coil 12. The coil 12, preferably a flat coil on a printed-circuit board formed from a spiral shaped printed conductor, is secured to the bondhead 1. The plate 11 is secured to the shaft 5. The output signal of the inductive sensor is proportional to the distance between the plate 11 and the coil 12. When the chip gripper 2 is deflected in relation to the bondhead 1, then the plate 11 moves with the chip gripper 2 while the position of the coil 12 does not change. The distance between the plate 11 and the coil 12 therefore reduces corresponding to the degree of deflection. The shaft 5 is optionally rotatable on its longitudinal axis so that any rotation of the semiconductor chip can be corrected before placing onto the substrate.

[0015] The integration of the touchdown sensor on the bondhead in combination with the pneumatic bearing of the chip gripper on the bondhead offers advantages which have an effect on the picking of the semiconductor chip from the foil as well as on the placing of the semiconductor chip onto the substrate. In the following, different methods are described in more detail that concern the picking of the semiconductor chip from the foil.

[0016] With these methods, as a rule an adjustment phase and an operating phase are foreseen. Each time a new foil with semiconductor chips for processing is presented on the wafer table, the operating phase is interrupted and the z height of the surface of the semiconductor chips is determined in an adjustment phase. Therefore, to begin with, an adjustment phase is carried out in order to determine a height z_M that corresponds to the z height of the surface of the semiconductor chips. From the height z_M a height z_0 is derived that serves in the operating phase as a parameter for the lowering of the bondhead and enables an optimum z movement of the bondhead. This adjustment phase comprises the following steps:

a) A semiconductor chip on the foil is selected and the wafer table brought into a position in which the selected semiconductor chip is located underneath the chip gripper 2.
b) The bondhead 1 is lowered to a predetermined z height at which the chip gripper 2 does not yet touch the semiconductor chip. An overpressure is applied to the pressure chamber 8 so that the piston 7 rests on the wall 10 of the pressure chamber 8. The chip gripper 2 is therefore in its resting position. The overpressure corresponds for example to the pick force desired in the following production phase. The output signal U of the inductive sensor is constant.
c) The bondhead 1 is now lowered at a constant speed. As soon as the chip gripper 2 strikes the semiconductor chip, the chip gripper 2 stops while the bondhead 1 lowers further. The chip gripper 2 is therefore deflected in relation to the bondhead 1 whereby the distance between the plate 11 and the coil 12 of the inductive sensor reduces. During this phase c, the z height of the bondhead 1 and the output signal U of the inductive sensor are continuously detected and saved as value pairs (z_i, U_i) whereby the index i denotes a whole number.
d) As soon as the output signal of the inductive sensor reaches a predetermined value, the lowering of the bondhead 1 stops and the bondhead 1 is raised again.
e) The value pairs (z_i, U_i) form a characteristic curve 13 that typically shows the course presented in Fig. 2. From the value pairs (z_i, U_i) the height z_M is now determined with customary mathematical methods.

[0017] The height z at which the chip gripper 2 comes into physical contact with the semiconductor chip is designated as height z_A. From Fig. 2, it can be seen that the output signal U does not diminish immediately from the height z_A but only somewhat later because the suction organ 4 itself contracts a little and the deflection of the chip gripper 2 in relation to the bondhead 1 only starts afterwards. The curvature of the characteristic curve 13 in the area of touchdown is characteristic for the type of suction

organ 4 used. It is therefore preferably foreseen to determine a correction value z_k for each type of suction organ and to store this on the Die Bonder so that when determining the height z_M from the value pairs (z_i, U_i) the actual physical height z_A of the upper surface of the semiconductor chip can be calculated thanks to knowledge of the correction value z_k.

[0018] It is preferable to carry out the adjustment process for several different semiconductor chips in order to subsequently determine a height that is here also designated as height z_M which is more characteristic of the detected height of the surface of the semiconductor chips on the foil.

[0019] In the following, a simplified adjustment method is explained in order to determine the average z height of the surface of the semiconductor chips:

a) A semiconductor chip on the foil is selected and the wafer table brought into a position in which the selected semiconductor chip is located underneath the chip gripper 2.
b) The bondhead 1 is lowered to a predetermined z height at which the chip gripper 2 does not yet touch the semiconductor chip. An overpressure is applied to the pressure chamber 8 so that the chip gripper 2 is in its resting position at which the piston 7 rests on the wall 10 of the pressure chamber 8. The overpressure corresponds for example to the pick force desired during the following production phase. The output signal U of the inductive sensor is saved as the value U_0.
c) The bondhead 1 is now lowered at a constant speed. As soon as the chip gripper 2 strikes the semiconductor chip, the chip gripper 2 stops while the bondhead 1 lowers further. The output signal U of the inductive sensor therefore continuously diminishes. When the output signal U reaches the value $U_1=U_0-\Delta U$, the z height of the bondhead 1 is read out as height z_J, the lowering of the bondhead 1 stopped and the bondhead 1 raised again.
d) The z height of the surface of the semiconductor chip is determined from the height z_J and the value ΔU under consideration of the characteristic curve 13 of the sensor.

[0020] The simplified adjustment method is preferably carried out for several semiconductor chips and then the average height z_M of the surface of the semiconductor chip determined.

[0021] Subsequently, a height z_0 is derived from the average height z_M. The height z_0 derived from the height z_M is used in order to continually optimise the speed of the bondhead during lowering for the subsequent processing of the wafer so that, on the one hand, the time duration for lowering the bondhead up to standstill is as short as possible and that, on the other hand, the impact impulse, ie, the impulse with which the chip gripper impacts on the semiconductor chip, is small enough to exclude damage to the semiconductor chip, the chip gripper and/or the needle holder. The processing of the semiconductor chips can take place in various ways whereby the height z_0 detected by means of the adjustment process plays a role now explained in more detail.

[0022] Picking of the semiconductor chip from the foil takes place by means of the controlled combination of bondhead 1, chip gripper 2 and a needle or a needle block with several needles in the following generally designated as needle 14. Fig. 3 shows for the pick process the z height of the bondhead 1 (solid line 15), the z height of the chip gripper 2 (broken line 16) and the z height of the needle 14 (solid line 17) in the course of time t. The deflection of the chip gripper 2 with reference to the bondhead 1 is equal to the difference between the solid line 15 and the broken line 16. Figs. 4A to 4C show different snapshots during the pick process. These figures show semiconductor chips 19 stuck to a foil 18 which are to be picked one after the other and placed onto a substrate, the bondhead 1, the chip gripper 2 and the needle 14. The needle 14 is part of a not presented chip ejector (known in the trade as a die ejector). The chip ejector holds the underneath of the foil 18 firmly during the pick process by means of vacuum. With this example, the height z_0 is given by

$$z_0 = z_M + \Delta z, \qquad (1)$$

whereby the parameter Δz has a positive value.

[0023] In a first phase that lasts up to the point in time t_1, the bondhead 1 is lowered at maximum speed, braked as late as possible and, without touching the semiconductor chip 19, brought to a standstill at height z_0. A predetermined overpressure is applied to the pressure chamber 8. The chip gripper 2 is in its resting position as the overpressure prevailing in the pressure chamber 8 presses the piston 7 against the wall 10. The chip gripper 2 does not touch the semiconductor chip 19. The needle 14 is raised so far that it just touches the underneath of the foil 18. The z height of the foil 18 is designated as z_f. This condition is presented in Fig. 4A.

[0024] In a second phase that lasts from point in time t_1 up to point in time t_2, the bondhead 1 remains at the height z_0. The needle 14 is raised at a controlled speed until it reaches a predetermined height z_1. In doing so, the needle 14 penetrates the foil 18 and raises the semiconductor chip 19. The semiconductor chip 19 comes firstly into contact with the chip gripper 2 and then deflects the chip gripper 2 in relation to the bondhead 1: The semiconductor chip 19 is now clamped between the chip gripper 2 and the needle 14. This condition is presented in Fig. 4B. The pick force exerted by the chip gripper 2 on the semiconductor chip 19 is independent of the degree of deflection of the chip gripper 2 in relation to the bondhead 1 and is only dependent on the pressure prevailing in the pressure chamber 8. In this way, the deflection of the chip gripper 2 can be kept comparatively low. The value of parameter Δz should, on the one hand, be so large that, on lowering, the bondhead 1 does not touch the semiconductor chip 19 or, when it does touch it momentarily as the result of overswing, that the force exerted on the semiconductor chip 19 in any case remains less than the pick force. On the other hand, the parameter Δz should be so small that the semiconductor chip 19 can not tilt on detaching from the foil 18 by means of the needle 14.

[0025] In a third phase that begins at point in time t_2, the bondhead 1 is raised again and then moved

away in horizontal direction in order to place the semiconductor chip 19 onto the substrate. In doing so, the deflection of the chip gripper 2 reduces continually. As soon as the deflection has reached the value of zero as is presented in Fig. 4C, the bondhead 1 takes the chip gripper 2 and the semiconductor chip 19 upwards with it.

[0026] With the example shown in Fig. 3, the third phase only begins after the needle 14 has reached its maximum height z_1. The third phase can however be started earlier, namely as soon as the deflection of the chip gripper 2 has reached a predetermined minimum value and before the needle 14 has reached its maximum height z_1. It must only be ensured that the chip gripper 2 remains deflected in relation to the bondhead 1 until the needle 14 has reached its maximum height z_1. The point in time t_2 at which the bondhead 1 is raised again can either be programmed as a fixed time or be derived from the signal delivered by the touchdown sensor during the second phase. That means, the touchdown sensor then triggers the point in time t_2 at which the bondhead 1 is raised again.

[0027] With a further development of this method, that is explained based on Fig. 5, a further process step is foreseen that is carried out after the needle 14 has reached its maximum height z_1 and before the deflection of the chip gripper 2 in relation to the bondhead 1 reaches the value zero. This process step consists of applying vacuum to the pressure chamber 8 as soon as the semiconductor chip 19 has detached itself sufficiently from the foil 18. In Fig. 5, this happens at point in time t_3 at which the needle 14 has already reached its set height z_1 but before the point in time t_2 at which the bondhead 1 is raised again. This leads to the piston 7 and therefore also the chip gripper 2 being moved away from the needle 14 at considerably greater speed in comparison with the example according to Fig. 3, whereby the piston 7 comes to stop at an upper stop of the bondhead 1. In doing so, detachment of the semiconductor chip 19 from the needle 14 is controlled and fast. This reduces the risk of the semiconductor chip 19 shifting or turning on detaching from the needle 14.

[0028] As the touchdown sensor is integrated into the bondhead 1, each time a semiconductor chip 19 is picked it is possible to measure the deflection of the chip gripper 2 in relation to the bondhead 1 at a suitable point in time and to calculate from this the actual height z_{ist} of the surface of the picked semiconductor chip that it had before being picked. The suitable point in time is after the point in time t_1 when, on the one hand, the bondhead comes to a standstill at height z_0 and, on the other hand, the needle 14 has reached its set height z_1. The extent of deflection of the chip gripper 2 is dependent on the actual height z_0 occupied by the bondhead 1. The height z_0 can now be updated at specific points in time in that a new value z_0' is calculated for the set height:

$$z_0' = z_{ist} + \Delta z. \qquad (2)$$

Updating of the height z_0 based on the value z_0' is preferably done by means of methods customary in statistics so that a possible individual faulty measurement does not lead to a deterioration of the pick

process.

[0029] With a further method designated as overtravel, the height z_0 is determined so that it is less by a predetermined overtravel distance Δz_1 than the average height z_M of the surface of the semiconductor chip: $z_0 = z_M - \Delta z_1$. The overtravel distance Δz_1 is selected so that the height z_0 is lower than the least expected height of the surface of the semiconductor chips 19. The bondhead 1 is lowered at maximum speed and brought to a standstill at height z_0. From the point in time of impact on the semiconductor chip 19 the chip gripper 2 is increasingly deflected in relation to the bondhead 1 and exerts the pick force defined by the pressure applied in the pressure chamber 8 on the semiconductor chip 19. The improved knowledge of the z height of the surface of the semiconductor chips 19 and the position independent pick force as a result of the pneumatic bearing of the chip gripper 2 make it possible to keep the overtravel distance Δz_1 much smaller than with prior art. A smaller overtravel distance Δz_1 means that the chip gripper 2 only impacts in the very last phase of lowering onto the semiconductor chip 19 where the bondhead 1 is already strongly braked and its speed on impact is very low.

[0030] With the examples described up to now, the lowering of the chip gripper 2 takes place indirectly during the process step a in that the chip gripper 2 is brought into a limit position, namely its resting position, with reference to the bondhead 1 and the bondhead 1 or the entire Pick and Place system with the bondhead 1 is lowered. With the following example however, the bondhead 1 is not movable in the z direction. For this, a drive is present that directly controls the z position of the chip gripper 2.

[0031] Fig. 6 shows a bondhead 1 with a pneumatic drive for the chip gripper 2. With this embodiment, the coil 12 is located underneath the metallic plate 11. The pneumatic drive comprises two pressure chambers 20 and 21 that are connected via pipes to a valve system 22 that is supplied with compressed air. The valve system 22 is controlled by a regulator 23. The inductive sensor comprising the metallic plate 11 and the coil 12 not only serves as touchdown sensor but as displacement sensor for measurement of the deflection of the chip gripper 2 in z direction with reference to the stationary arranged bondhead 1. A first pressure sensor 24 serves the measurement of the pressure p_1 prevailing in the first pressure chamber 20, a second pressure sensor 25 serves the measurement of the pressure p_2 prevailing in the second pressure chamber 21. The output signals of the inductive sensor or the two pressure sensors 24 and 25 are fed to the regulator 23 as input values. The regulator 23 delivers control signals for control of the valve system 22. The regulator 23 works in two operating modes. In the first operating mode, the deflection of the chip gripper 2, ie, the z position, or a value derived from it is controlled. The inductive sensor delivers a signal proportional to the deflection $z_{ist}(t)$ as a function of time t and the regulator 23 controls the valves of the valve system 22 according to a given characteristic $z_{soll}(t)$. In the second operating mode, the pressure difference $p_1 - p_2$ is controlled that produces the bond force to be applied by the chip gripper 2. Further information on such a bondhead can be taken from the European patent

application No. 01204781.7 to which explicit reference is made herewith.

[0032] In the following, it is now described based on Fig. 7 how the pick process is carried out with this bondhead 1. The height z_0 is again given by the equation (1). The broken line 16 shows the course in time of the z height of the chip gripper 2. The solid line 17 shows the course in time of the z height of the needle 14.

[0033] In the first phase, which lasts up to point in time t_1, the chip gripper 2 is lowered at maximum speed, braked as late as possible and, without touching the semiconductor chip 19, brought to a standstill at height z_0. In doing so, the regulator 23 works in the first operating mode in which it controls the deflection of the chip gripper 2, ie, the z position or a value derived from it. The needle 14 (Fig. 4A) is raised so far that it just touches the underneath of the foil 18.

[0034] In the second phase, which lasts from point in time t_1 up to point in time t_4, the chip gripper 2 firstly remains at height z_0. The needle 14 is raised at a controlled speed until it reaches a predetermined height z_1. In doing so, the needle 14 penetrates the foil 18 and raises the semiconductor chip 19. At point in time t_4, the semiconductor chip 19 firstly comes into contact with the chip gripper 2 and then deflects the chip gripper 2 in relation to the bondhead 1: The semiconductor chip 19 is now clamped between the chip gripper 2 and the needle 14. As soon as the chip gripper 2 is deflected in relation to the bondhead 1, the output signal of the inductive sensor changes whereupon the regulator 23 has to increase the pressure p_1 prevailing in the first pressure chamber 20 in order to continue to keep the z height of the chip gripper 2 constantly at the height z_0. While however, on the other hand the needle 14 has to reach the height z_1, a change in the z height of the chip gripper 2 has to be possible and allowed. This can be made possible in different ways.

[0035] A first possibility exists in limiting the maximum allowed pressure difference $p_1 - p_2$ and in fact to a value that corresponds to the pick force to be applied. The regulator 23 therefore continues to work in the first operating mode whereby the allowed pressure difference $p_1 - p_2$ is limited either from the point in time t_1 at which the chip gripper 2 has reached the height z_0 or from the point in time at which the needle 14 is raised. (During lowering of the chip gripper the pressure difference $p_1 - p_2$ does not have to be limited.) The regulator 23 tries to hold the chip gripper 2 at the height z_0. But, because the pressure difference $p_1 - p_2$ is limited to the pick force, it is not able to withstand the force of the needle 14. The chip gripper 2 is therefore raised.

[0036] A second possibility exists in switching the regulator 23 from the first operating mode to the second operating mode as soon as, after starting to raise the needle 14, the output signal of the inductive sensor changes by more than a predetermined value which can be interpreted as the start of deflection of the chip gripper 2. In the second operating mode, the pressure difference $p_1 - p_2$ is controlled

corresponding to the pick force to be applied.

[0037] In the third phase which begins at point in time t_3, vacuum is applied to pressure chamber 20 and overpressure is applied to pressure chamber 21 in order to abruptly raise the chip gripper 2 until the piston 7 is controlled at an upper position or comes to rest at an upper limit stop whereby the semiconductor chip 19 detaches itself from the needle 14 and then the bondhead 1 moves away in horizontal direction in order to place the semiconductor chip 19 onto the substrate. In doing so, the regulator 23 works either in the first operating mode in which it controls the z position of the chip gripper 2 or in the second operating mode in which the pressure difference $p_1 - p_2$ is controlled so that the chip gripper 2 is moved upwards until the piston 7 is stopped at an upper limit stop.

[0038] While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art having the benefit of this disclosure that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims and their equivalents.